THE PROGRESS OF THE TELEGRAPH

I.

IN the present day scientific research makes such rapid progress, and produces such wonderful results, that the mind ceases to appreciate the advancement, which can only be realised by looking back, from time to time, to ascertain what was the condition of any special branch, any given number of years ago. It is only necessary to retrace time some twenty-five years, and in almost every department of practical science the step by step advancement may be traced, from sewing machines to steam hammers; from lucifer matches to lighthouses. But, perhaps, in no department of the applied sciences has scientific research been productive of more valuable and practical results than in the vast arena of electrical investigation; and great as has been the progress made in this department, still the knowledge obtained tends only to point out the vast field of research open to the student in discovering those fundamental laws and harmonies in nature's laboratory at present concealed from our view.

Sufficient, however, is already known in this special department of knowledge to inform us that electrical action and activity enters largely into the constitution of the solar system, regulating, in some degree at present not understood, the relation between the sun and our globe, as regards various terrestrial phenomena; as well as the disturbances upon the solar disc in relation to our earth's terrestrial and magnetic currents, as demonstrated in the daily deviations of the compass, and auroral displays in the regions adjacent to the polar latitudes of the earth Thus we see that whatever may be the vast field of research that remains to the student in this branch of scientific investigation, most important results have been developed. Time has been almost annihilated, and in the race between the earth's revolution on its axis, and electrical speech, man's inventive genius has been victorious—time and space being so far distanced that in electrical transmissions from one part of the globe's surface to another, time has no value as measured by the earth's rotation; messages sent from India and the East arriving hours before the time of their despatch. The introduction of the electric telegraph is quite within the memory of the present generation. Up to 1844 electrical knowledge was more or less confined to the lecture-table; crude experiments upon frictional electricity and the elements of magnetic and voltaic phenomena constituted the portfolio of knowledge as accepted by the public. The profound researches of Oersted in 1819 in relation to the influence of a current of electricity upon the magnetic needle is of great importance and may be summarised as follows:—A magnetic needle poised on a pivot so as to move freely in a horizontal plane adjusts itself in what is termed the magnetic meridian. If a metallic wire is placed parallel to the needle at a little distance above it, and a current of electricity is passed through the wire, the magnetic needle will no longer remain parallel to the wire, but, leaving the magnetic meridian, will set itself across the current; and the same effect will be produced if the wire is placed below the needle, and it will be found that if the direction of the current in passing through the wire is from S. to N., the north pole of the needle will be deflected in an opposite direction to where the current is passed from N. to S.; in other words, when the current passes horizontally *over* the needle, that pole which is nearest to the negative end of the battery always moves to the *west*, and when the current is passed under the needle the same pole will deviate to the east. Ampère in 1820, who employed the magnetic needle, the coil of wire, and the galvanic battery, to indicate signals, developed the principles of the discovery of Oersted, and demonstrated the fact that currents themselves exert an influence on other currents. From the importance of Ampère's experiments in relation to all telegraph apparatus, a few words clearly illustrating the action of the current upon the magnetic needle are necessary.

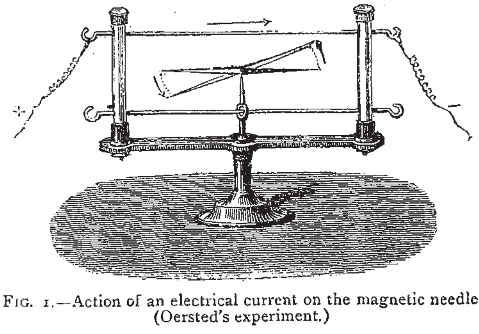

FIG. 1.—Action of an electrical current on the magnetic needle. (Oersted's experiment.)

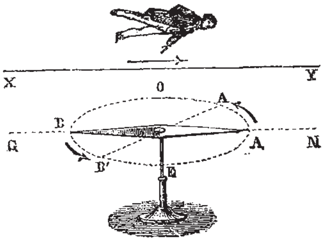

FIG. 2.—Deviation of the southern pole towards the left, under the influence of the upper current.

If the observer regards himself as the conductor or connecting wire placed parallel to the needle, and whose face in every position is turned towards the centre of the needle, and the current from the positive pole of the battery to the negative pole is supposed to enter his feet and pass out at his head, the current will be found to develop a right and left influence on the magnetic needle, corresponding to the right and left of the person himself: so that *when an electric current acts on a magnetic needle, the south pole of the needle*—which is that which is directed towards the north—*is deviated towards the left.* Figs. 2 and 3 illustrate this: for when the parallel current is passed above the magnetic needle, the south pole A is deflected to A′ to the left of the current, or towards the *west;* and on the current being passed below the needle, the same pole is deflected to A′, being still to the left of the observer, but in this case the pole A has moved to the *east.* Ampère also demonstrated that when two metallic wires are traversed simultaneously by an electrical current, the wires are either attracted towards or repelled from each other according to the relative directions of the two currents. Thus, when they move in the same direction through the parallel wires, they attract each other, while they repel each other if they move in a contrary direction. Two non-parallel currents attract each other, if both are approaching or receding from the direction of the apex of the angle formed by the ends produced, while they will repel each other if one of the currents approach, and the other recedes from the apex of the angle. Fig. 4 illustrates the three cases of attraction and two cases of repulsion to which these laws of Ampère's refer. Ohm in 1827, who put forward his celebrated formulæ relating to the quantity of the galvanic

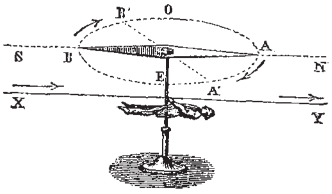

FIG. 3.—Deviation to the left of the current. Lower current.

current; Faraday in 1831, who discovered the electric current induced in a hollow coil of wire when a steel permanent magnet or an electro-magnet is introduced or withdrawn from the coil; and Wheatstone, who in 1843 proposed to register observations of astronomical instruments with a view to determine longitude, and who shortly afterwards published, in the *Philosophical Transactions*, his investigations into the laws that regulate the transmission of electric currents through metallic conductors — were not then developed into any practical form; it was only about that time that public attention became directed to the probable future of the electric telegraph. The exhibition instruments open to the public at one shilling each, between Paddington and Slough, were the means of bringing to justice the perpetrator of a foul crime. These early double-needle instruments, long since obsolete as regards construction, have been preserved as indicating the first era in telegraphic communication.

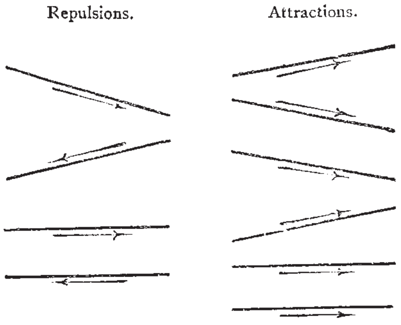

FIG. 4.—Law of the attraction and repulsion of a current by a current.

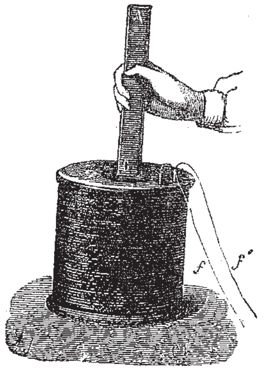

FIG. 5.—Induction by a magnet.

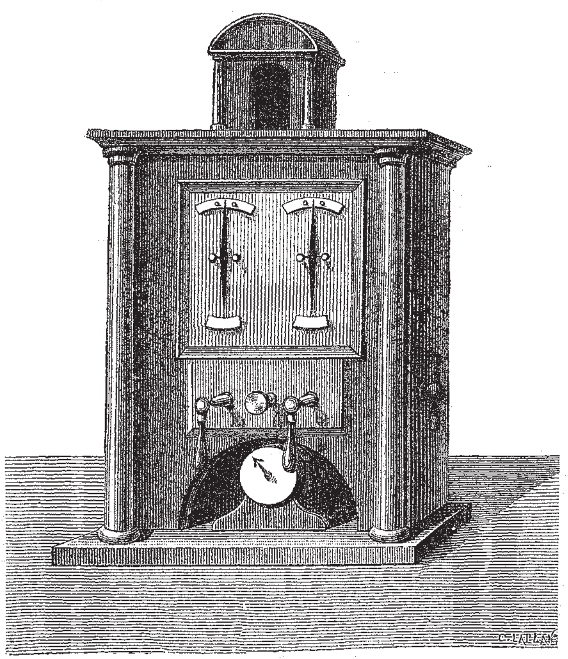

FIG. 6.—The Cook and Wheatstone double-needle Telegraph: 1845.

In those days electrical knowledge was in its infancy: the very wire between Paddington and Slough was insulated partly by silk and suspended through goose-quills attached to the posts along the Great Western Railway. In those days of electrical innocence the practical value of the return-circuit by means of the earth was undeveloped. As early as 1840 Wheatstone first conceived the idea and published his plans for transmitting messages under the sea by means of a submarine cable. That scientific men at that time considered that such a discovery would lead to most important results is testified to by the Abbé Moigno, who writes that it was announced by Wheatstone in 1840 that he had found the means of transmitting signals between England and France, notwithstanding the obstacles of the sea; and he emphatically adds: "I have touched with my hands the conducting wire which, buried in the depths of the ocean, will unite instantaneously the shores of England with the shores of France." In 1844, at Swansea Bay, off the Mumbles Lighthouse, the first practical experiment took place, and signals were transmitted from an open boat to the shore from a considerable distance. In the boat sat the inventor, Wheatstone, his eyes eagerly watching his galvanometer for the coveted signals—signals that would tell him his hopes were realised, and that he had triumphed over the elements. The last twenty-eight years have given birth to many wonderful and practical results. Between 1844 and 1848 railways were in their infancy; their limit of distance as compared with their present extent was very circumscribed. Equally so was electrical knowledge, as compared with the requirements of extended distance. In 1848 Holmes gave to telegraphy the practical result of his researches as regards the rapid transmission of signals over extended circuits. In those early days the five-inch astatic needles and coils of the Cook and Wheatstone system were absolutely useless for longer distances than one hundred miles, and as railways extended, so telegraphic difficulties were

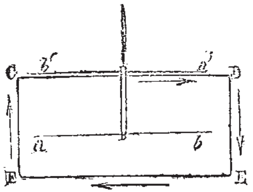

FIG. 7.—System of two magnetic needles, with their poles reversed, forming an astatic combination, neutralising the effects of terrestrial magnetism.

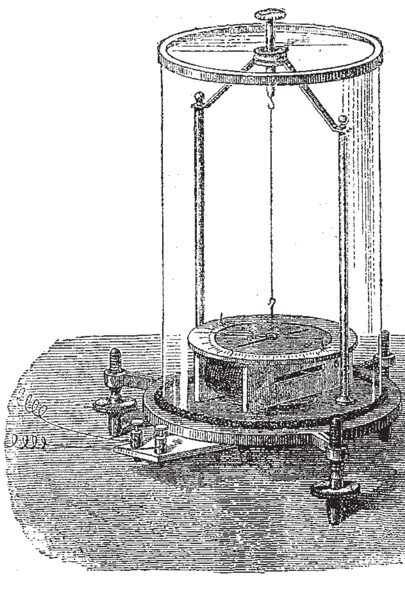

FIG. 8.—Astatic Galvanometer.

found to multiply. The introduction of gutta-percha in 1850 and a more perfect knowledge in the preparation of indiarubber as insulating mediums for electrical purposes have been the means of establishing upon a commercial basis electric communication between the chief empires of the earth, have united the eastern and western hemispheres by metallic highways of thought, threading the trackless ocean with its mysterious depths. It is thus that the primitive experiment of Wheatstone in 1844 has developed into the stupendous telegraphic undertakings that encircle the globe, uniting with a common interest all nations, creeds, and languages.

The principal laws that regulate the transmission of electric currents through metallic conductors are simple, and may be briefly described with sufficient distinctness to enable the general reader to grasp the intricacy and magnitude of the science of electric transmissions.

Leaving on one side the old accepted terms of conductors and non-conductors, for the present purpose all substances in nature must be regarded as able more or less to conduct a current of electricity.

As the various substances, gums, glass, wood, earths, liquids, or metals are examined, it will be found that some afford much greater facility for the transmission of electricity than others; consequently, if they are arranged according to the resistance offered to the current, a list somewhat similar to the annexed will be presented, commencing with those of least resistance: copper, iron, plumbago, sea-water, rain-water, snow, steam, moist earth, oils, ice, phosphorus, porcelain, baked wood, dry paper, hair, silk, mica, glass, wax, sulphur, shellac, gutta-percha, india-rubber. It therefore naturally follows that where it is required to construct a system of submarine circuits for the conveyance of electric currents from one place to another, some metal, such as copper, is selected. Water being also pretty high in the scale, it is essential that to prevent leakage or loss of current in its passage through the wire, a gum such as gutta-percha or india-rubber, offering a high resistance, should be selected in which to enclose the conducting wire and give proper insulation to the circuit. It is therefore evident that the perfection or freedom from loss or leakage in an electric circuit is simply relative as regards the material employed, and insulation means the obstruction or resistance placed in the way to prevent the escape of electricity from the conducting wire. Various important phenomena come into play in connection with the passage of an electric current through an insulated circuit, which it is necessary to explain in an elementary manner. Induction, or the production of an electric current moving in an opposite direction to that of the current passing through the insulated conductor, takes place in the adjacent medium to that of the insulated wire; that is to say, supposing an insulated metallic circuit—a submarine cable—is fulfilling its duties in the transmission of an electric current throughout the metallic conductor, the effect of that current will be to set up a second current in the water moving in an opposite direction. This opposite or induced current is well illustrated by the Leyden jar familiar to everyone. The inside metallic foil represents the copper wire, the glass separating the foils the insulation of the cable, the external metallic coating the water surrounding the cable. On electrifying the Leyden jar the internal and external metallic coats become charged with electricity in opposite states. The effect of this induced current on submarine cables is to retard or pull back the flow of the primary current, sensibly diminishing the speed of transmission as compared with that of a land line of telegraph. On a land line with a single wire the effect of induction does not take place, because the metallic conductor, generally iron, requires no insulating medium to enclose it, the air itself taking the place of the insulator; the wire requires to be insulated only at the points of support, the tendency of these being to produce a leakage or weakening of the current from water and other substances held in suspension in the air, impairing the integrity of the contacts at the points of suspension. Induction, however, takes place with land wires under certain conditions, namely, when two or more are suspended closely together; a current through one wire will then produce an induced current in an opposite direction in an adjacent wire. Induction increases with the extent of surfaces of the copper conductor and the insulator with which it is covered diminishing the speed of transmission.

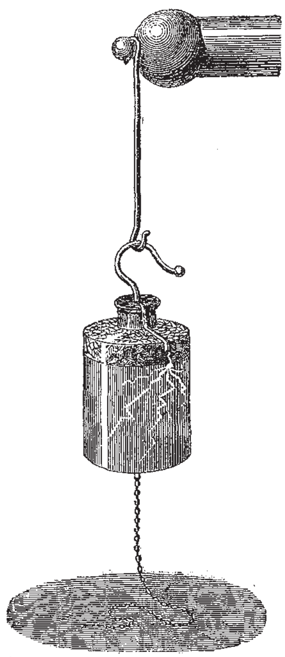
FIG. 9.—Charging the Leyden jar.

Insulation may be obtained by a very thin covering of the insulating medium. Increase in the thickness of the material only mechanically renders the covering more secure. The effects of induction are decreased in proportion as the insulating substance is increased in thickness, the conducting wire remaining the same; with an infinite insulation like the atmosphere, induction would cease.

With insulated wires, absorption (inductive capacity) takes place. No substance in nature has yet been found that will not absorb some other element, force, or matter in a greater or less degree. Heat, light and electricity, liquids, gases, and metals under varied conditions are all alike susceptible, and will either be influenced or retain in different proportions the various elements, forces, or matters brought into juxtaposition with them. At present it is only necessary to investigate the phenomenon of electrical absorption or inductive capacity. Thus, when a current of electricity passes through an insulated metallic circuit, certain known effects take place. Resistance, which impedes the direct progress of the current; induction, or the setting up of a counter-current moving in an opposite direction, and exerting, as it were, a pulling back of the original current; absorption, or the sucking up into the substance of the insulating material of a sensible integrant of the original current. Various insulating gums, as gutta-percha and indiarubber, have different properties as regards the insulation or resistance to the lateral escape of the electric current they enclose, namely, the inductive effect in proportion to the insulation, and the absorption of the current as it flows through the conducting wire enclosed by them. As a sponge sucks up water, so to a certain extent does the insulator of the submarine wire absorb the electric current, the result being that, instead of the current passed into the wire at one end flowing through and emptying itself out at the other end of the wire, the current will flow out and leave a residue behind, an appreciable time being required for discharge to clear the line. This absorption of the current leaves the line clogged for the receipt of the next current, and greatly interferes with the rapid transmission of currents through insulated metallic circuits. It is therefore only in short cables that the transmission of the current may be considered instantaneous. In cables exceeding 150 miles in length, electric currents have a sensible duration.

(*To be continued.*)